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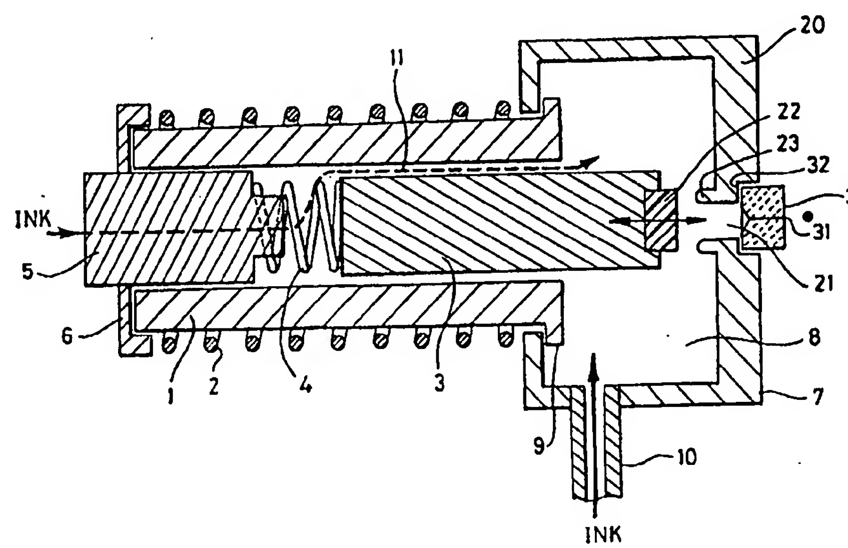

(57) Abstract

The present invention relates to a method for assembling an ink ejection device, notably a solenoid valve for use in an ink jet printer, having an ink chamber from which ink is adapted to be ejected through a nozzle orifice member mounted in or on an outlet directly from the chamber, characterised in that the nozzle orifice member is mounted after the ink chamber has been flushed out to remove dirt or debris therefrom. Preferably, the nozzle orifice member is removably mounted so that it can be removed to permit servicing or repair of the device at a later date. The invention also provides an ink ejection device for use in the method of the invention having a removable nozzle orifice member.

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TITLE: METHOD FOR ASSEMBLING DEVICES

The present invention relates to a method for assembling devices, notably print heads for ink jet printers.

BACKGROUND TO THE INVENTION:

Print heads for ink jet printers typically comprise a chamber through which the flow of ink to a fine bore nozzle orifice is controlled by a valve, transducer or other actuator.

In a typical valved print head, ink flows under pressure to the valve chamber of a valve having a plunger which opens and closes an outlet to the chamber to discharge droplets of ink from a nozzle orifice. In some forms of such a valve, the orifice takes the form of a fine bore capillary tube outlet from the valve chamber or a jewel nozzle orifice mounted directly in the outlet to the valve chamber. Such a construction can be modified so that a number of valve plungers operate within a single valve chamber upon a number of outlets to the chamber so that the outlets are formed as a row in a nozzle plate forming one wall of the valve chamber. Alternatively, a number of valves can be grouped together, each feeding one of a series of jewel or other outlet nozzles set into a nozzle plate as one or more rows of nozzle outlets. The valve plunger is typically the core piece of an electromagnetic solenoid and is moved axially by the action of a coil wound around the body of the valve.

In an alternative form of print head, the plunger is a rod of piezoelectric crystal which expands and contracts axially when a voltage is applied to the crystal. Alternatively, the crystal can act upon a cantilever arm to cause the arm to flex and thus move its free end into and out of sealing engagement with the nozzle orifice.

In the above forms of print head, the supply of ink is under

pressure and the valve mechanism controls the flow of ink so as to eject a drop of ink at the desired moment from the nozzle orifice.

In a further alternative, ink is fed under low pressure to an ink chamber and is then ejected from that chamber through a nozzle providing sufficient back pressure due to the surface tension effects at the meniscus of the ink at the nozzle orifice to prevent the flow of ink through the nozzle due to the low pressure applied. The necessary impetus to eject ink through the nozzle orifice is provided by a transducer or other actuator acting directly on the ink or acting on a wall of the chamber to alter the volume of the chamber. Thus, a piezoelectric crystal can extend into the ink chamber or can form a wall of the chamber so that application of a voltage to the crystal causes a change in the internal volume of the chamber so that a droplet is ejected from the nozzle orifice. The piezoelectric crystal can also be mounted on a wall of the chamber so as to cause the wall to flex and thus change the internal volume of the chamber.

The above forms of ink jet print head will for convenience be denoted as drop on demand print heads hereinafter.

In a further type of print head, ink is caused to flow through a fine bore nozzle orifice, for example a jewel nozzle orifice, under sufficient pressure to form a jet of ink at the nozzle. This jet is broken up into a stream of uniformly sized and spaced droplets by applying pressure pulses or vibration at high frequency to the ink, to the nozzle or to the ink chamber. This stream of droplets can then be guided by applying a charge to the ink jet and passing the charged droplets formed from the charged jet through a deflecting electric field so that they land at desired positions on a substrate passing the nozzle orifice. Such ink jet print heads will for convenience be denoted as continuous jet heads hereinafter.

In all the above forms of ink jet print head, ink is ejected from a chamber through a nozzle orifice under the influence of a mechanism associated with the ink chamber. However, problems are encountered during manufacture and initial use of such print heads. Thus, where the nozzle orifice is incorporated in the outlet to the ink chamber, as is usually the case with all types of continuous jet printers and with many forms of drop on demand printer, problems are encountered in flushing away any dirt or debris trapped in the ink chamber during manufacture. Also, due to the fine bore of the nozzle orifice, air is usually trapped in the ink chamber as ink is fed to the chamber initially. This air can detrimentally affect the operation of the ink chamber, notably with drop on demand printers where a valve head operates within the ink chamber.

It is therefore customary for the operator to provide means for flushing the print head out to remove solids and debris and to provide a purge system for removing air trapped in the ink chamber. Both these requirements are considered vital to the efficient operation of an ink jet printer, but introduce complexity and additional flow lines and control systems into the design and manufacture of the head. Furthermore, the ink or flushing fluid used in such flushing operation must be discarded at the start up of the print head and represents an additional cost.

Such problems are reduced where the nozzle is remote from the ink chamber, for example when the valve in a drop on demand printer is located some distance from the nozzle orifice and is connected thereto by an ink flow line. In such cases, the valve can be flushed out separately from the remainder of the print head. However, due to their simplicity of design and operation, it would be desirable to construct drop on demand print heads so that their nozzle orifices were mounted close together so as to be able to use drop on demand technology to print small characters. This requires that the nozzle orifices be formed as a series in a single ink chamber, each nozzle

being controlled by its own valve mechanism so that the jewels or capillary tubes forming the nozzles are mounted directly at the outlets to the ink chambers. It would also be desirable to mount the nozzle orifice at the outlet to the ink chamber of a valve, or in the spigot forming the outlet to the ink chamber of the valve during manufacture of the valve. This would allow the valve/nozzle assembly to be made under factory conditions of cleanliness and accuracy. The assembly can then be calibrated under factory conditions so that each valve would be sold as meeting a given performance requirement. Such a design would also minimise the amount of air entrapped forward of the plunger seal in the ink chamber in the valve and would reduce the amount of ink from which solvent could evaporate through the nozzle orifice between operation of the valve.

However, such a design runs contrary to the requirement for ease of flushing and purging of entrapped air due to the presence of the nozzle orifice at the outlet to the valve and despite the apparent benefits of mounting the nozzle orifice at or closely adjacent the outlet to the valve, the majority of ink jet printers use valves which are mounted remotely from the nozzle orifice.

We have now devised a method by which the contradictory requirements of factory assembly and calibration and the requirements to flush out the ink chamber and purge trapped air can be reconciled.

Surprisingly, we have found that the orientation of the axis of the bore through a nozzle orifice in an ink jet printer, notably a drop on demand printer, does not have to be accurately aligned with the intended line of flight. Due to the small distances to be travelled by the droplets between the nozzle orifice and the surface of the substrate on which the droplet is to be printed, minor variation between the alignment of the nozzle bore axes in a multi-nozzle array can be tolerated without unacceptable loss of print image quality.

Therefore, the nozzle orifices do not have to be inserted into the nozzle plate or other support under closely controlled factory conditions as had been considered essential hitherto. It is thus possible to insert the nozzle orifices at the site of use. This enables the ink chamber to be flushed out without the nozzle orifice in place, thus reducing the risk of blockage of the nozzle bore by any dirt or debris in the valve or other parts of the ink flow system. The nozzle orifice can then be inserted when flushing has been completed. This enables a manufacturer to assemble and test a valve or print head and to flush out dirt and debris before the nozzle orifice is mounted in position, so that a clean assembly is achieved; and then to insert the nozzle orifice to provide the fully assembled print head which can then be calibrated. Alternatively, provided that adequate clean conditions can be provided, a user can remove the nozzle orifice from a valve or print head during service or repair of the valve or head and can then flush that through before completing re-assembly of the valve or head.

SUMMARY OF THE INVENTION:

Accordingly, the present invention provides a method for assembling an ink ejection device having an ink chamber from which ink is adapted to be ejected through a nozzle orifice member mounted in or on an outlet directly from the chamber, characterised in that the nozzle orifice member is mounted after the ink chamber has been flushed out to remove dirt or debris therefrom.

The term directly in relation to the outlet from the ink chamber is used herein to denote that the outlet in or on which the nozzle orifice member is to be mounted is provided either as an aperture in a wall of the chamber or is provided immediately adjacent to the chamber, as when the outlet takes the form of a short spigot outlet tube, so that the nozzle orifice member is within 1 cm of the ink chamber. The outlet forms an integral part of the ink chamber wall and is not

carried by a separate component, as is the case where the nozzle orifice member is mounted at the end of a tube connected to the spigot forming the outlet to the ink chamber.

It is particularly preferred that the nozzle orifice member be demountably secured in the ink chamber outlet so that it can be removed for subsequent service or repair of the nozzle or ink chamber, for example re-flushing of the chamber where the ink jet print head incorporating it has stood for some time or the ink has been contaminated with solids.

Accordingly, from another aspect, the invention provides an ink ejection device having an ink chamber from which ink is adapted to be ejected through a nozzle orifice member mounted in or on an outlet directly from the chamber, characterised in that the nozzle orifice member is demountably mounted on or in the outlet whereby the nozzle orifice member can be mounted after the ink chamber has been flushed out to remove dirt or debris therefrom and can be removed subsequently thereafter.

The invention further provides an ink jet printer or printer head comprising an ink ejection device of the invention.

Whilst the invention can be applied to any type of ink jet printer head incorporating an ink chamber, the invention is of especial use in the manufacture of valves for use in drop on demand ink jet printers. For convenience, the invention will be described hereinafter in terms of this preferred use.

Typically, the valve will comprise a generally cylindrical body about which is wound an electrical coil which moves a plunger axially within the body. At one and of the body is formed an ink chamber which typically has an axially orientated outlet bore through the end wall of the ink chamber. The plunger carries a sealing end face or member which engages the outlet and opens or closes the outlet as the plunger is moved axially by applying an electric current to the coil, usually against an

axial spring bias which holds the plunger in the outlet closed position until a current is passed through the coil. In one form of such a device, the ink chamber is provided as a transversely elongated chamber or manifold with a row of such outlets in one of the long walls of the chamber or manifold, each served by a separate plunger. In such designs, the plungers may be connected to the sealing end member by a wire or rod so that the main body/coil/plunger part of the valve can be mounted remotely and operate the sealing end member through the wire or rod. Such a construction enables the outlets to the ink chamber be placed closely together, which might not otherwise be possible where the main parts of the valve were mounted in close proximity to one another on a wall of the chamber or manifold. For convenience, the invention will be described hereinafter in terms of a single valve incorporating a single ink chamber, rather than a multiple outlet chamber/valve mechanism assembly.

The ink chamber has one or more ink inlets thereto, for example a radial spigot or port through the side wall of the chamber, or is fed with ink which passes axially along ducts or the annular gap around the plunger from an inlet at the other end of the body of the valve. The ink is fed under pressure, typically 0.25 to 1 bar but higher pressures may be used if desired, so that the ink will eject through the outlet when the plunger is retracted.

The plunger carries an end face seal or end member which sealing engages the outlet to the ink chamber, for example by mating against the internal end face of the ink chamber or by seating upon one or more upstanding sealing ribs formed internally upon the end wall of the ink chamber around the outlet; or vice versa. Alternatively, the outlet to the ink chamber can be provided by or with a stainless steel or similar capillary tube which forms an outlet spigot to the valve. The tube can project inwardly into the ink chamber to provide a complete or incomplete upstanding annular rim around the outlet

bore against which the end face or member of the plunger seals. In a further alternative, the jewel forming the nozzle orifice member as described below can project into the ink chamber to provide a convex end face against which a transverse seal carried by the end of the plunger, or such a seal face formed upon the end face of the plunger, sealingly engages.

The outlet aperture in the chamber wall or the free end of the spigot tube passing through the wall is provided with a nozzle orifice member. Preferably, this takes the form of a garnet or other jewel having the necessary fine bore therethrough to form the nozzle orifice required to form the small sized droplets for printing. In present designs, this jewel is cemented securely in place during manufacture of the valve and prior to any testing or flushing through of the assembled valve. In the method of the invention, the nozzle orifice member is not inserted into the chamber outlet until the assembly of the valve has been completed and the assembled valve has been flushed through to remove any debris or dirt which may have been trapped in the chamber during the manufacturing process.

The nozzle orifice member can be a simple tight push fit within the bore of the outlet from the ink chamber or can be secured in place with adhesive or cement, by straps or other mechanical or other securing means. However, it is preferred that the nozzle orifice member be demountably secured in the chamber outlet, for example by the use of a temporary cement or a hot melt adhesive. Alternatively, the nozzle orifice member, for example the jewel, can be securely mounted in a cap member which is a screw, bayonet or other fit onto the free end of the spigot outlet to the ink chamber or is a screw fit within a recess in the outer face of the ink chamber wall to register with the bore of the outlet aperture through the ink chamber wall. Other forms of demountable mounting for the nozzle orifice member may be used, depending upon the construction of the valve and its ink chamber.

Where a push fitted nozzle orifice member is employed, this is preferably a push fit into a uniform cylindrical bore through the end wall of the ink chamber of the valve. However, the bore of the outlet to the ink chamber may be formed with a reduced diameter section at its inner end so as to provide a wider diameter bore within which to locate and mount the nozzle orifice member. In this way an annular seat or shoulder is provided in the bore against which the nozzle orifice member engages when it is mounted correctly in the bore. This seat or shoulder serves to assist alignment of the nozzle orifice member and to ensure that the nozzle orifice member does not extend into the ink chamber, which could otherwise impair the sealing engagement of the end of the plunger with the inner face of the chamber wall or the rim of the tube forming the outlet. However, where the end face of the nozzle orifice member, for example the jewel, is formed appropriately, for example with a convex end face as described above, the nozzle orifice member can project into the ink chamber to form a seat against which the end face of the plunger seals.

Apart from the provision of the nozzle orifice member as a component which is fitted after the valve assembly has been assembled and flushed out, the design, construction and operation of the valve can be conventional and can use conventional techniques.

The assembled valve of the invention is flushed out to remove dirt and debris which may have been trapped in the valve or in the ink supply system of the ink jet printer head before the fine bore nozzle orifice member is mounted in position. This enables particles which would otherwise be trapped within the assembly to be flushed out, preferably at the site of manufacture so that factory standards of cleanliness can be achieved. The flushing is carried out using conventional techniques and fluids. The nozzle orifice member can then be mounted in the ink chamber outlet using any appropriate technique and the assembled valve or print head then tested and

calibrated to provide a finished product ready for use. Where the nozzle orifice member is removably mounted, the nozzle orifice member can be removed to permit flushing out of the valve or print head at a later date, for example to remove debris and/or air from the printer ink lines where the printer has stood for some time or to enable a blocked or worn nozzle orifice member to be replaced.

DESCRIPTION OF THE DRAWINGS:

To aid understanding of the invention, it will now be described by way of illustration with respect to preferred embodiments as shown in the accompanying drawings in which Figure 1 is a diagrammatic axial cross-section of a conventional solenoid valve modified according to the invention; Figure 2 is a diagrammatic transverse cross-section through an ink chamber having a number of outlets; and Figure 3 is a diagrammatic axial cross-section through an impulse ink jet printer head.

DESCRIPTION OF THE PREFERRED EMBODIMENTS:

As shown in Figure 1, a typical solenoid valve for a drop on demand ink jet printer comprises a tubular body 1 having wound or mounted upon it a substantially co-axial electrical coil 2. Located within the axial bore of the body 1 is a plunger 3 which moves axially under the influence of a bias spring 4 and the coil 2. The spring 4 is restrained by an end pole piece 5 which also limits the retraction of the plunger 3 when a current is applied to the coil 2. The pole piece 5 is a typically a screw fit in the body 1 and that end of the bore in the body is sealed by an end cap 6.

At the other end of body 1 is mounted a second end cap 7 which forms the ink chamber 8 at that end of the body. End cap 7 is typically a firm push fit upon the end of body 1. However, if desired, cap 7 can be secured in position by being crimped upon a radially projecting rim or shoulder 9 carried by body 1. A

transverse ink inlet 10 to chamber 8 is provided in a side wall of the end cap 7. Alternatively, the ink inlet can be provided through the pole piece 5 so that the ink flows axially along the annular gap 11 between plunger 3 and body 1 and axially into chamber 8 as shown dotted.

The end wall 20 of the chamber 8 is provided with an axially directed outlet 21 through which ink is ejected when the plunger 3 is retracted by coil 2 to break the seal between the end of the plunger and the rim of the outlet and thus expose the bore of the outlet to the ink in chamber 8. When no current flows in coil 2, plunger 3 is urged by spring 4 into sealing engagement with the end wall 20 to prevent flow of ink through the outlet 21. In order to enhance the sealing engagement between the end face of plunger 3 and the inner face of end wall 20, the end face of the plunger can be provided with a rubber or plastics sealing disc or pad 22 and the end wall 20 can carry an upstanding complete or interrupted annular rib 23 which bears against the sealing disc or pad 22, or vice versa.

The nozzle orifice member for the valve is provided by a jewel 30 having a fine bore 31 therethrough. Preferably, the jewel is a tight push fit within the bore of outlet 21 so that the jewel is held firmly within the outlet bore during use, but can be inserted or removed if desired by a simple push action. Preferably, the jewel has a convex end face which protrudes into the ink chamber 8 to provide a seat against which the disc or pad 22 on the free end of the plunger seats to close the outlet to chamber 8. Alterna-tively, as shown in Figure 1, the bore of outlet 21 is provided at its axially inward end with a radially inward projection or annular rib or shoulder 32 against which the axially inward face of the jewel bears when it is seated properly home in the bore of outlet 21. This seating serves to locate the jewel axially in the outlet bore and also serves to assist correct axial orientation of the bore through the jewel.

As stated above, the valve is assembled without the jewel nozzle orifice member 30, so that the valve and the print head in which it is mounted can be flushed out to remove solids. The jewel nozzle orifice member 30 can then be inserted to complete the valve assembly, which can then be calibrated and it performance adjusted to provide a valve having known characteristics.

As indicated above, the invention can be applied to other forms of ink chamber. Thus, as shown in Figure 2, the ink chamber can be in the form of an elongated manifold type chamber 40 with a number of outlets 41 formed in one long wall 42 thereof. Each outlet is opened and closed by a plunger 43, and the design and construction of the outlets and the plunger end faces can be similar to that described above for the single valve of Figure 1. The plungers 43 are reciprocated by rods 44 connected to remotely located solenoid assemblies 45, thus allowing the outlets 41 to be spaced closely together in wall 42. Each outlet 41 is provided with a jewel nozzle orifice member 46 as in the device of Figure 1 and chamber 40 has an ink inlet 47 located at one end thereof. If desired, an ink outlet 48 can be provided at the other end of chamber 40 to allow ink to flow along chamber 40 when the outlets 41 are all closed, so as to minimise settling or drying out of the ink.

The invention can also be applied to other forms of ink jet printer head, for example an impulse droplet ejection device as shown in Figure 3. In such a device, the print head com-prises an ink chamber 50 having an axially directed outlet 51 which can be fitted with a jewel nozzle orifice member 52 as described for the valve of Figure 1. The chamber 50 is provided with an inlet 53 for ink at low pressure, so that the surface tension of the meniscus at the orifice in the nozzle orifice member 52 prevents any flow of ink through the nozzle. In order to overcome this surface tension restraint, the chamber can be provided with a piezoelectric crystal 54 which extends axially towards the bore of the nozzle in member 52 as

shown. When a voltage is applied to the crystal 54, it extends axially to drive ink ahead of its end face into and through the bore of the nozzle orifice in member 52.

Alternatively, the crystal 54 can be in the form of a cantilever arm which flexes so that its free end moves towards the inlet to the bore in nozzle orifice member 52 to drive ink ahead out it through the nozzle orifice bore. In a further alternative, a wall of the chamber, for example the side wall 55, is provided with or formed from a piezoelectric crystal 56 so that the wall can be flexed to change the internal volume of the chamber, as shown dotted in Figure 3, and thus eject a drop of ink through the nozzle orifice bore in member 52.

In all the above cases, the nozzle orifice member is mounted in position after the ink chamber of the print head has been flushed out, as described for the valve of Figure 1.

CLAIMS:

1. A method for assembling an ink ejection device having an ink chamber from which ink is adapted to be ejected through a nozzle orifice member mounted in or on an outlet directly from the chamber, characterised in that the nozzle orifice member is mounted after the ink chamber has been flushed out to remove dirt or debris therefrom.

2. A method as claimed in claim 1, characterised in that the nozzle orifice member is demountably secured to or in the bore of the ink chamber outlet.

3. An ink ejection device having an ink chamber from which ink is adapted to be ejected through a nozzle orifice member mounted in or on an outlet directly from the chamber, characterised in that the nozzle orifice member is demountably mounted on or in the outlet whereby the orifice can be mounted after the ink chamber has been flushed out to remove dirt or debris therefrom and can be removed subsequently thereafter.

4. A method as claimed in either of claims 1 or 2 or a device as claimed in claim 3, characterised in that the ink ejection device comprises a drop on demand solenoid valve having a terminal ink chamber within which the plunger of the valve is adapted to move axially into and out of sealing engagement with an axially orientated outlet from the ink chamber through a transverse end wall to the chamber.

5. A method or device as claimed in claim 4, characterised in that the end face of one of the end wall of the ink chamber and the plunger carries a sealing member and the other carries one or more upstanding annular ribs which are adapted sealingly to engage the said sealing member.

6. A method or device as claimed in claim 5, characterised in that the outlet to the ink chamber is provided by a tubular

member and the end of the tubular member projects into the ink chamber to provide the annular sealing rib.

7. A method or device as claimed in any one of the preceding claims, characterised in that the nozzle orifice member is located within the bore of the outlet to the ink chamber.

8. A method or device as claimed in claim 7, characterised in that the bore is provided with an internal shoulder or radial projection against which the nozzle orifice member seats.

9. A method or device as claimed in any one of the preceding claims, characterised in that the nozzle orifice member is a push fit within the bore of the ink chamber outlet.

10 A method or device as claimed in either of claims 1 or 3 substantially as hereinbefore described with respect to and as shown in any one of the accompanying drawings.

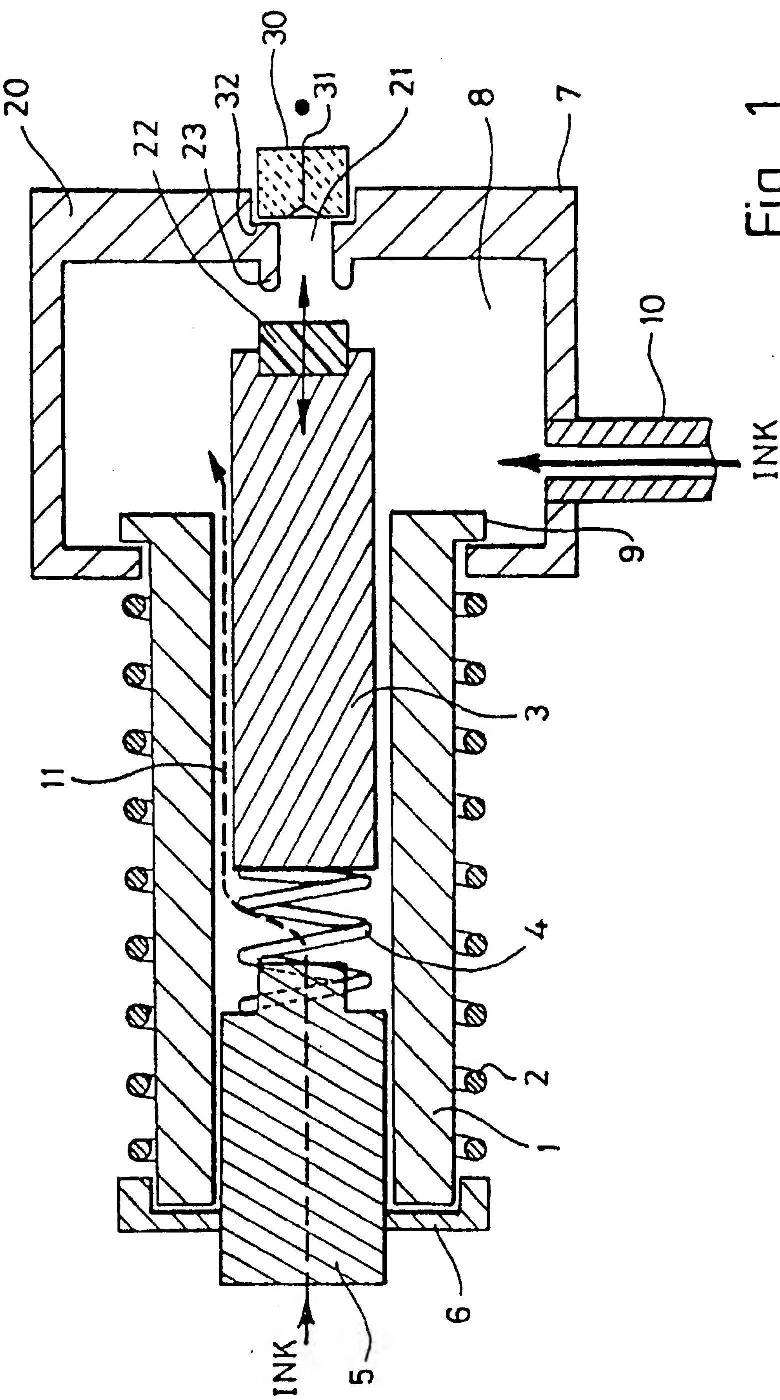

Fig. 1

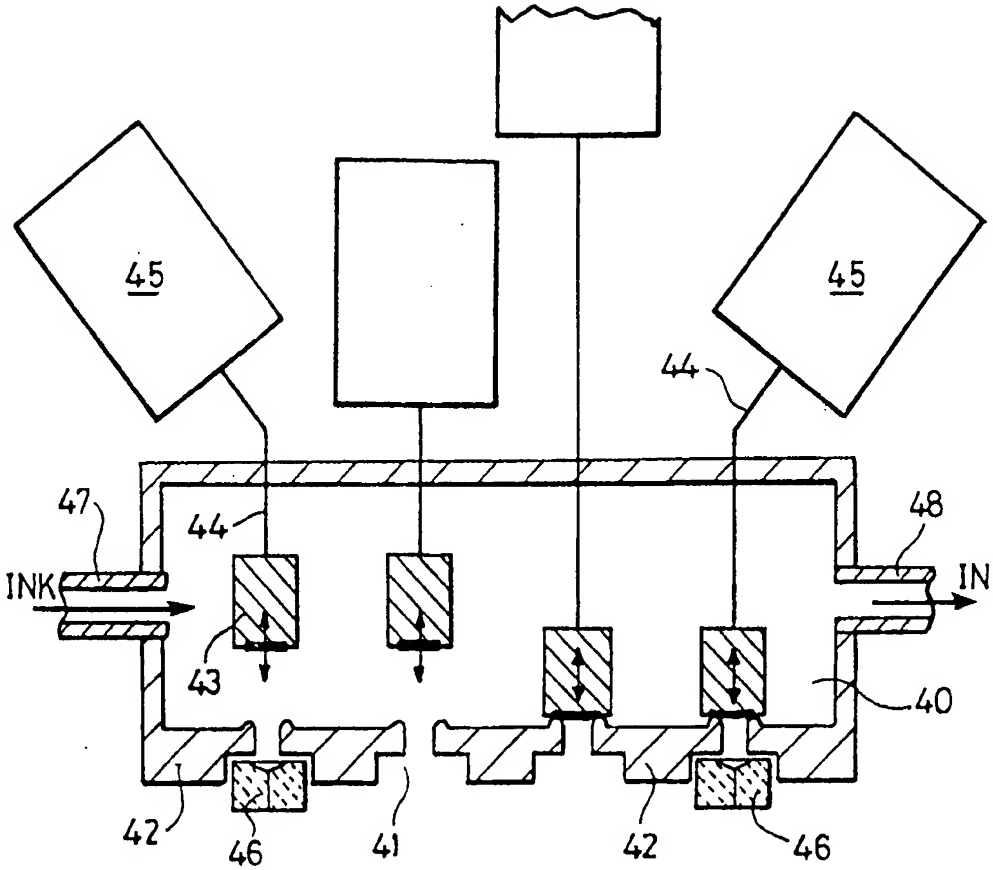

Fig. 2

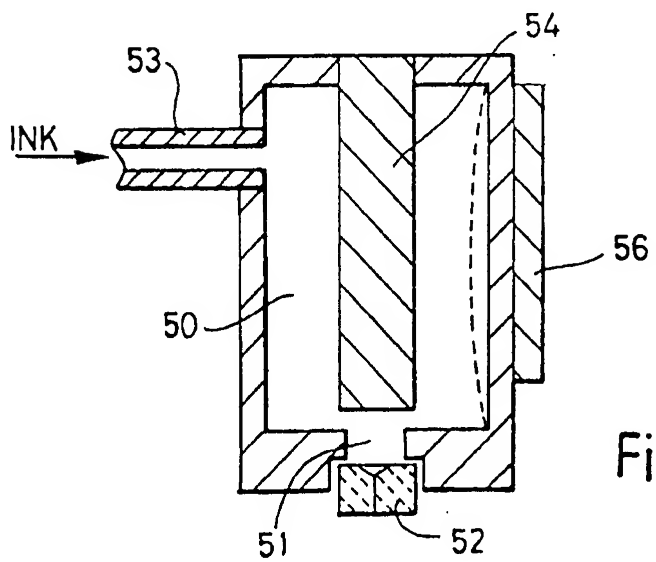

Fig. 3